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ABSTRACT

Instructional development should be based on theory rather than raw empiricism. The dimensions and possible form of an instructional theory are outlined in three premises. It was presumed that a limited set of behavior categories exist and that all behaviors can be calssed into one or more of these categories. It was also presumed that for each category there exists an optimal information processing strategy which would promote most efficiently and effectively the acquisition of that behavior. It was also presumed that the purpose of instruction is to manipulate task variables in such a way that students are facilitated in using the appropriate information processing strategy. One aspect of an instructional theory is described in relation to concept learning. An experimental investigation is described, together with steps for applying these principles to instructional development. (Author/MBM)

INSTRUCTIONAL RESEARCH AND DEVELOPMENT



# Toward a Theory-Based Approach To Instructional Development

M. David Merrill

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# TOWARD A THEORY-BASED APPROACH TO INSTRUCTIONAL DEVELOPMENT[1]

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In the swing of the educational pendulum we have arrived at the point where the now thing is the development of instructional products. The initials R, D, D and E are on the very top of the current list of "in" words. At the recent AERA meetings, it was evident to all present that the name of the organization this year could just as well be changed to the American Educational Development Association. The U. S. Office of Education is stressing the development of educational products and is currently spending what money is available in development efforts. It seems very appropriate that we pause for a moment to examine the state of the art and to address ourselves to the question, "What is instructional development?"

## A Current Model of Instructional Development

In spite of the many papers which have been written and the many flow charts which have been drawn illustrating the development process, almost every position includes the four elements illustrated in Fig. 1. Perhaps the single most talked about topic in the area of ID is the specification of instructional objectives. It is pretty much agreed that unless

one has specified what it is a student will be able to do, it is difficult to specify instructional activities which will help him reach the goal. Perhaps less widely implemented, but widely discussed, are pretests. Most writers on the topic of ID have suggested that there is no need to teach a student some behavior which he has already acquired. Furthermore, to profit maximally from a given instructional product, a student is required to have attained a certain level of prerequisite skill. It is therefore advocated that having specified our objectives, the next part of an instructional development package should assess the student's prerequisite skills and his ability to already do the task being taught. The third, and most widely implemented component, is the preparation of instructional activities. This organization has been active over the past several years in stressing multi-media use in the presentation of instructional activities, unfortunately, whether or not they have had demonstrated value. The fourth component is the posttest. Some measurement must be attempted to assess the degree to which the student has acquired the objectives.

In Fig 1. the arrows from the posttest back to the instructional experiences and to the objectives indicate the iterative nature of development. Trying an instructional package with students means that adjustments must be made either in the instructional materials or in the objectives if the student is to acquire the behavior that is specified.

Widely Accepted Instructional Development Premises

Several premises are usually associated with current instructional development efforts.

Premise 1: Objectives must be specified in terms of observable student behavior.

Thousands of pages have been written on the necessity of specifying behavioral objectives. There is probably no one involved in development who is not familiar with Mager's classic book on specifying instructional objectives. Mager summed it up when he wrote, "If you don't know where you're going, you're liable to end up somewhere else."

Premise 2: Only an instructional product which has been verified by empirical tryout should be considered a completed instructional development effort.

This might be labled the "if at first you don't succeed, try, try, again phenomena." On the current list of "in" words are expressions such as, "accountability" and "quality control," which being interpreted mean that instruction should set out to accomplish specific goals and data should be gathered to find out if in fact these goals are being accomplished. If they are not, the instruction should be modified to be certain that the goals are attained.

Premise 3: Tests used in instructional development should measure the students ability to perform specified behavior rather than how well he performs in comparison with his fellow students.

In technical language, tests whould be criterion-referenced rather than norm-referenced. A well-developed product does not evaluate a student on his ability to out-perform his fellow students, but on his ability to perform the behavior which is specified.

There are several problems associated with each of the above presumptions.

Premise 1: Objectives

(1) There is considerable question raised in some quarters about the value of behaviorally-stated objectives. It is frequently argued that as long as we are dealing with trivial behavior such as memorization or the learning of facts, it is a relatively simple matter to specify objectives; but when one deals with important behavior, such as problem solving or learning basic concepts of the field, behavioral objectives are no longer important because what is learned by the student is something other than observable behavior. This objection can be boiled down to the question "How does one specify complex types of learning in terms of student behavior?"

(2) A second limitation of behavioral objectives is that after spending considerable time writing objectives, they are too frequently neatly typed, filed in a drawer, and forgotten. The use to which objectives can be put is not always obvious to the developers of instructional materials. Unanswered questions include: How does one use an objective to construct appropriate learning experiences? How does one use an objective to construct appropriate evaluation experiences? How does one use objectives or a set of objectives to appropriately sequence materials? I think this limitation can be summarized by the question, "After objectives, what?"

Premise 2: Empirical tryout

The "try, try again phenomena" is one of the real advances in instructional development. The greatest limitation is not this approach per se, but the way the development is guided prior to the empirical tryout. The procedure most often used is the "raw empiricism" approach. Instructional activities are designed using the best folklore and tradition currently available. The package is then tried to see if it "works." If not, it is revised until success is attained or the budget is exhausted. This process is extremely time consuming and, consequently, very expensive. Instructional materials developed on the first round are rarely, if ever, adequate in meeting and promoting the specified behavior. Too frequently they are not successful even after several revisions. The solution in too many cases has been to modify the objectives, assuming the initial objectives were unattainable.

An alternative to the raw empiricism approach is a theory guided development. This approach assumes that instructional theory can be specified and validated so that when used to guide development, many of the tryout-revised cycles would be eliminated. Given adequate instructional theories, it is possible that objectives could be attained in a period of time unlikely to ever be discovered by the trial and error of a raw empiricism approach.

Premise 3: Criterion-referenced tests

While considerable has been said about the importance of basing

tests on the objectives and measuring the student's ability to perform a particular behavior rather than his ability to perform better than another student, there are numerous problems associated with this approach. Most serious is that advocates of this approach, especially in the programed instruction world, have flagrantly ignored that which is known about classical test theory and have consequently developed completely unreliable tests. If a test is unreliable, it cannot possibly be valid. Hence it measures nothing. The problem is easily illustrated. In many programs a single test item is used to measure a relatively complex behavior. It has been pointed out by Gagne (1970) and others that complex behaviors require a set of items for adequate measurement, rather than a single item. Furthermore, reliability is a product of repeated measurement. The attempt to measure complex behavior with a single item does not provide enough repetition to make any inferences about subsequent occurances of this behavior.

A second problem associated with criterion-referenced tests is that in spite of our preachments, the tests we use frequently do not follow from the objectives. The most frequent is that many tests measure only memorization skills in spite of the fact that the objectives specify problem solving or concept using behavior. Part of the problem stems from lack of ability to specify complex objectives.

## TOWARD AN INSTRUCTIONAL THEORY

In the next few paragraphs I would like to suggest some additional premises. These presumptions are not currently in wide use in instructional

development, nor, I am sure, would they be accepted universally by those who presume the statements previously identified. I believe, however, that they do make possible the beginning outline of an instructional theory which might have some power in guiding theory-based instructional development.

> Premise 4: It is presumed that there is a limited number of different kinds of behavior and that any instructional outcome is an instance of one or more of these behavior classes.

This means that a given educational goal or objective can be classified into one or more behavior types. Conversly, each educational objective is not unique in itself but is similar to a set of other educational objectives in terms of the kind of behavior change required. Further, these classes of behavior run across subject matter lines. That is, objectives can be identified in English, mathematics, science, social sciences, home economics, auto mechanics, and physical education which are similar or identical in terms of the kind of behavior they require. Classification into a given behavior class is a result of the critical behavior required and the critical conditions under which that behavior must be observed. The word critical is used here to differentiate behavior and conditions which may vary and still have the objective remain a member of a particular behavior class (Merrill, 1971 a).

The behavior classes identified, can be arranged in hierarchical continuum. That is, the behavior at one point in the continuum requires as

a prerequisite some behavior in each of the previous classes. The horizontal axis in Fig. 2. suggests such a continuum from emotional behavior through problem solving based on the work of Robert Gagne (1970) and subsequent modifications of Merrill (1971 a). These categories have been described elsewhere and a detailed description of the basis for classification will not be repeated here.

> Premise 5: It is presumed that for each behavior class an optimal information processing strategy can be identified which if used by a student provides for optimal attainment of the specified behavior.

While differences exist in some of the parameters of the strategies (Clark & Merrill, 1971) it is suggested that the optimal strategy for one student is the same as the optimal strategy for another student. This does not eliminate the importance of individual differences. While it is presumed that the optimal strategy required is universal, differences still exist in prerequisite skills which a student has previously acquired prior to undertaking a given task, in his motivation toward the task, and in the particular parameter values required within the task itself. The vertical axis in Fig. 2. illustrates these learner strategies. To avoid introducing confusing material for this presentation, the strategies are merely labeled level 1 to level 6. We do have some hypothesis about what such information processing strategies might look like, but these will be discussed at another time.

Corollary to this premise is that:

> Strategies used by students tend to approximate one or more of the optimal information processing strategies. While the strategy used by a student may vary somewhat from the optimal strategy, his success in acquiring the behavior will depend on the extent to which his strategy corresponds to the optimal strategy.

A second corollary to premise 5 is that:

> Given a task at a given behavioral level (see premise 4) the strategy used by a student in approaching the task may tend to approximate the strategy appropriate for a different level task rather than the strategy appropriate to the level of the task required by the behavior and conditions under which this behavior will be observed.

For example, when presented a list of names to memorize, students frequently employ a strategy which approximates a problem-solving strategy. If a strategy higher in level than the level of the task is employed, the learning may be successful but inefficient compared with the efficiency of the acquisition were the appropriate level strategy employed. It is also frequently the case that a student will attack a higher level task using a lower level strategy. A frequent example is to approach a concept-or problem-solving task with a memorization strategy. If this is the case, it is difficult or impossible for the student to adequately acquire the specified behavior.

The following fundamental presumption is the premise of the proposed instructional theory.

> Premise 6: It is presumed that by manipulating task variables, it is possible to facilitate the student's use of the appropriate optimal information processing strategy for a given type of behavior.

It is presumed that the primary purpose of instructional development is the manipulation of task variables in such a way that students will use appropriate strategies in acquiring given tasks. When instructional development has appropriately manipulated these task variables the resulting acquisition is maximally efficient, effective and enduring. It follows from this assumption that instructional theory is a set of prescriptions for this

manipulation of task variables. This premise is the central idea of this paper.

## AN EXAMPLE OF INSTRUCTIONAL THEORY VALIDATION AND ITS APPLICATION

At the American Educational Research Association in February (Merrill, 1971b) it was suggested that there are three levels of involvement with instructional design and development. Level one designers, teacher technicians or programers, are guided in their design efforts by cookbooks called "instructional design guides." These guides are so well specified that with very little training an instructional technician is able to develop appropriate instructional materials following the prescription of the guide. Level two, designers, instructional technologists or instructional engineers have two functions; first the development of instructional systems using all of the techniques and theory available, and second, the development of instructional design guides for use by those operating at the technician level. Level three designers, instructional psychologists or instructional scientists, have two levels of activity; first, the development of instructional theory and second, the validation of such a theory through experimental investigation in both laboratory and field situations.

For the remainder of this paper, I would like to describe a research program which is attempting to validate an instructional prescription for one level of task. Suggestions for using this prescription to guide instructional development will also be presented. The level of behavior involved is concept classification. At this level the critical behavior is that the student will be able to correctly identify class membership of some object or event or some representation of an object or event. The specific behavior might be matching the name to the object, or discriminating an instance from a non instance. The most critical condition under which this behavior must be observed is that the instance presented to the student must be one that he has not previously encountered; that is, one that has not previously been identified as a member or non member of the class in question. Again, a wide variety of specific conditions may be present. He may be presented a picture of the object rather than the actual referent, etc.

Fig. 3. shows, in simplified form, an optimal strategy for acquiring such a behavior. If a student is to adequately acquire the ability to classify instances, he must first observe an example that is an instance. While being shown this instance the relevant attributes may or may not be called to his attention. This is another question for instructional research, but one that we will ignore for the current discussion. Having examined the example, he is presented a non example which is matched to the example; that is, the non example resembles the example except for the relevant

attributes This promotes the ability to discriminate members of the class from non members of the class. If the non example is carefully matched to the example, then the student whould be able to observe those elements that are relevant and those that are not relevant. The third step is to present a divergent example. Most of the concepts with which we deal in school are so complex that they consist of many sub-categories and one example may differ considerably from another example. The example presented for this third step should be one that differs considerably from the first example. This allows the student to observe the attributes in a different context and promotes generalization to all members of the class. In step 4 this divergent example is also contrasted with a matched non example. This step promotes discrimination in a new context. The latter two steps are repeated depending on the complexity of the concept and individual differences. If there are numerous sub classes, then these steps need to be repeated until the student has seen the amount of variety possible within the context of the concept. Also, different individuals may need more repetitions than other individuals.

Earlier it was indicated that the purpose of this instruction is to manipulate task variables to promote the use of optimal strategy. At the present time three classes of task variables have been identified. (1) Prompting variables include hints, prompts, and other helps that are given to a student, and the kinds of knowledge of results given to a student about his response. (2) A second class of variables are stimulus similarity variables. How does one display or stimulus situation relate to another

display or stimulus situation? It is this class of variables that we have investigated with the studies to be described. (3) A third class of variables deals with sequence. In the current instance, do you present the example and the matched non example simultaneously or sequentially? There are other sequence questions dealing with random presentation versus systematic presentation, etc.

The studies to be described concentrated on stimulus similarity variables. Three specific stimulus similarity variables were identified. The first of these is one that is related to the difficulty level of an exemplar. Given an object to classify, some objects are easier to classify as a member of a class than others. In order to provide a more operational way of defining this particular variable, a probability level was calculated. A wide set of examples and non examples were administered to a sample of students after they were given a definition. They were asked to classify each of the instances presented as an example or non example of the defined concept. The percentage of students from the sample correctly identifying each instance as an instance and each non instance as a non instance were assigned to that particular item as the probability level. We have found that for most concepts which are taught in school, the distribution of percentages approximates a normal curve.

The second variable identified has already been described briefly as one we labeled "matching." An example is matched to a non example when the pair have irrelevant attributes which are identical or nearly

identical. Obviously there are degrees of matching, but for the experiment to be described, we simply used matched versus unmatched.

The third variable defined was divergent pairing. Divergent pairing relates examples to examples. A divergent pair of examples are two in which the irrelevant attributes are as different as possible. If the irrelevant attributes of two examples are the same, they are said to be convergent.

Markle and Tiemann (1971) had previously identified various types of classification errors which students frequently made in learning a concept task. These are overgeneralization, undergeneralization, and misconception. Overgeneralization occurs when the student correctly identifies all of the examples as class members plus identifying some non examples as members of the class. In other words, the student fails to discriminate between classes. Undergeneralization occurs when the student identifies the more obvious examples as class members but indicates that less obvious examples are not class members. In other words, he fails to generalize to all members of the class. A misconception occurs when the student falsely presumes that an irrelevant attribute or combination of irrelevant attributes is relevant. The operational consequence is that the student fails to recognize examples not having this attribute as class members and indicates that non examples that do have this attribute are class members.

Fig. 4. illustrates the hypothesized outcomes of the study. Summarized they are as follows:

(1) If the instances represent a range of probability, examples are matched to non examples, and examples are divergent with each other, then the student will learn to correctly classify previously unencountered instances.

(2) If instances are low probability, examples are not matched to non examples, and examples are divergent with each other, then students will tend to overgeneralize when classifying previously unencountered instances.

(3) If instances are high probability, examples are matched to non examples, and examples are divergent with each other then students will tend to undergeneralize when classifying new, unencountered instances.

(4) If instances range in probability level, examples are not matched to non examples, and all examples are convergent on some attribute or set of attributes then the student will demonstrate a misconception when attempting to classify previously unencountered instances.

Two experiments have currently been conducted with a third one underway. The concepts taught were trochaic meter, taught to college sophomores; adverbs, taught to junior high school students; and Rx2 crystal structures, taught to college sophomores. In each of these experiments a carefully constructed posttest allowed students to be scored on each of the classification errors identified above. There is not time to describe this test in detail. The reader is referred to the report of the original research. (Tennyson, Woolley & Merrill, 1971.) In every

experiment, the predicted outcome was supported at beyond the .001 level. The program designed to teach correct classification did teach correct classification. The hypothesized classification errors did result when progr. s were constructed to promote those errors. (See Fig. 4). Fig. 5. illustrates one of these sets of outcomes.

In summary, based on an instructional theory, specific "if-then" hypotheses were stated. Variables were carefully maniuplated and all of the theoretical predictions were substantiated at well beyond the chance level.

What implications does this research have for instructional development, and especially a theory-based instructional development? How would the preparation of a concept instruction lesson differ knowing the results of this experiment than would have been the case before? Having examined a large number of concept lessons, we have found that the typical procedure is to present a definition and one or two examples. Frequently the examples are convergent. Non examples, especially matched non examples, are almost never presented in concept lessons. Using the best folklore and tradition available, and the procedures typically used, we would predict that students would almost always undergeneralize or that they would frequently acquire misconceptions rather than to acquire correct classification behavior. No amount of empirical tryout under the "raw empiricism" procedure would eliminate the problems represented

here. With enough repetition, a developer may by chance stumble on to the correct combination of examplars and non exemplars. In most cases, however, either the objectives would be seen as too difficult, or repetition would proceed until a student on his own resources finally acquired the concept and eliminated errors in spite of the instructor.

The steps involved in constructing a concept lesson based on the limited amount of instructional theory that we have discussed are as follows:

Step 1. The attributes on which the object or event is classified are carefully identified and stated in a precise definition of the concept.

Step 2. A large number of exemplars and non examples are identified. The greater the variety that is found in this set of instances and non instances the better.

Step 3. Having collected this large pool of examples and non examples they are submitted to an instance probability analysis to determine the probability level of each instance and non instance.

Step 4. Prepare a comprehensive classification error test. This test is constructed to allow one to detect over-and under-generalization and misconception.

Step 5. A set of displays is prepared in which examples and non examples are carefully matched and in which examples are divergently paired. This set should be redundant enough to represent the complexity of the concept and to provide additional displays for students who may require more repetition than others.

Step 6. Conduct a dual control group validation study of the program. In comparison one, students receiving the program should be compared against students not receiving any instruction. In comparison two, students being presented a randomly selected set of instances should be compared with students receiving the carefully selected instances of the program. Based on the research that has been conducted thus far, it is hypothesized that a concept program constructed using these steps would require considerably fewer revisions and would be more effective than a concept program using the typical "raw empiricism" approach.

## SUMMARY

This paper has indicated that instructional development should be theory based rather than based on "raw empiricism." Second, the dimensions and possible form of an instructional theory were outlined in three premises. It was presumed that a limited set of behavior categories exist and that all behaviors can be classed into one or more of these categories. It was also presumed that for each category there exists an optimal information processing strategy which would promote most efficiently and effectively the acquisition of that behavior. Third, it was presumed that the purpose of instruction is to manipulate task variables in such a way that students are facilitated in using the appropriate information processing strategy.

One aspect of an instructional theory was described in relation to concept learning. An experimental investigation was described and

steps for applying these principles to instructional development were described.

FIGURE 1
WIDELY ACCEPTED COMPONENTS OF
AN INSTRUCTIONAL DEVELOPMENT MODEL

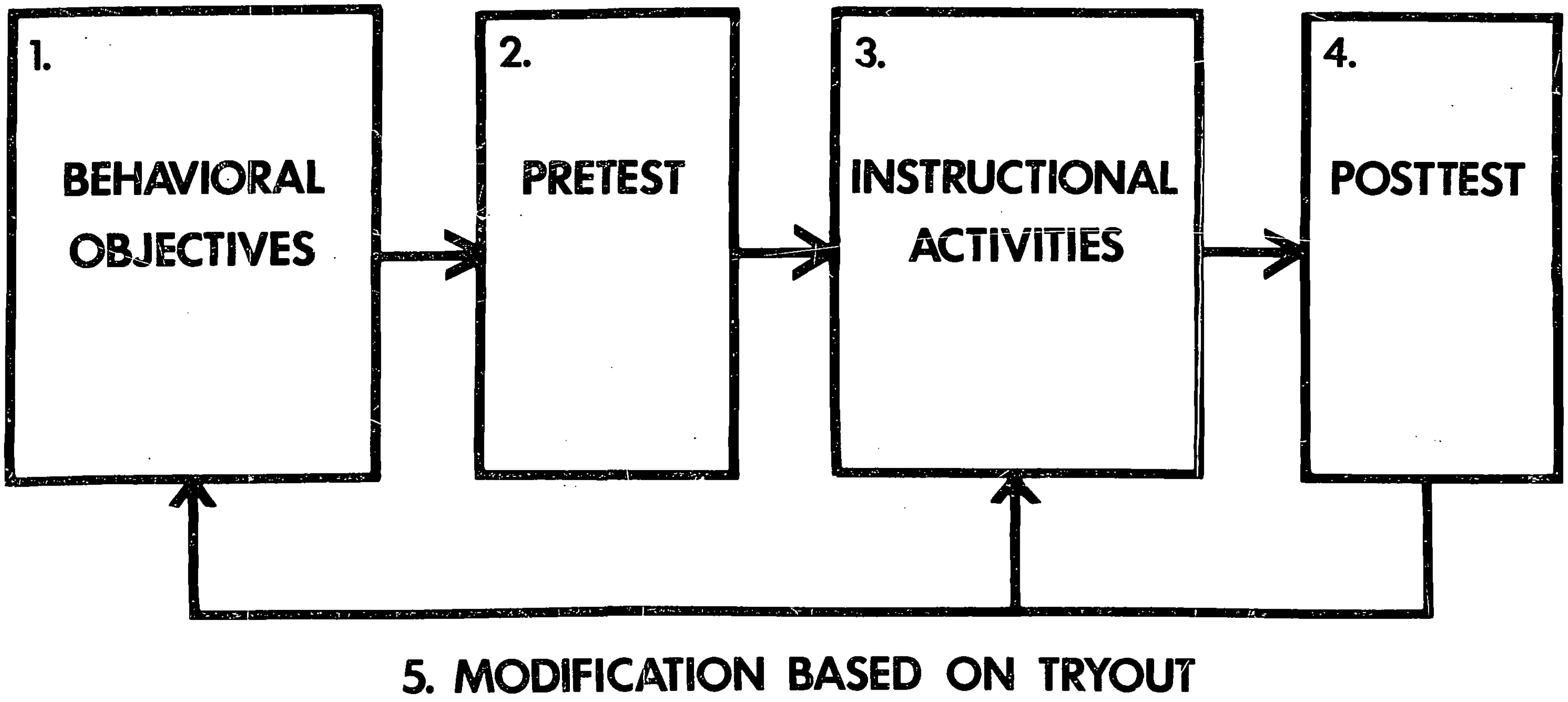


FIGURE 2

# PARAMETERS OF A THEORY OF INSTRUCTIONAL DESIGN

## LEVEL OF OBSERVED BEHAVIOR

| LEARNER STRATEGY | EMOTIONAL | PSYCHOMOTOR | MEMORIZATION | CLASSIFICATION | PRINCIPLE USING | PROBLEM SOLVING |
|---|---|---|---|---|---|---|
| LEVEL 1 | | | | | | |
| LEVEL 2 | | | | | | |
| LEVEL 3 | | | | | | |
| LEVEL 4 | | | | | | |
| LEVEL 5 | | | | | | |
| LEVEL 6 | | | | | | |

FIGURE 3 OPTIMAL CLASSIFICATION STRATEGY

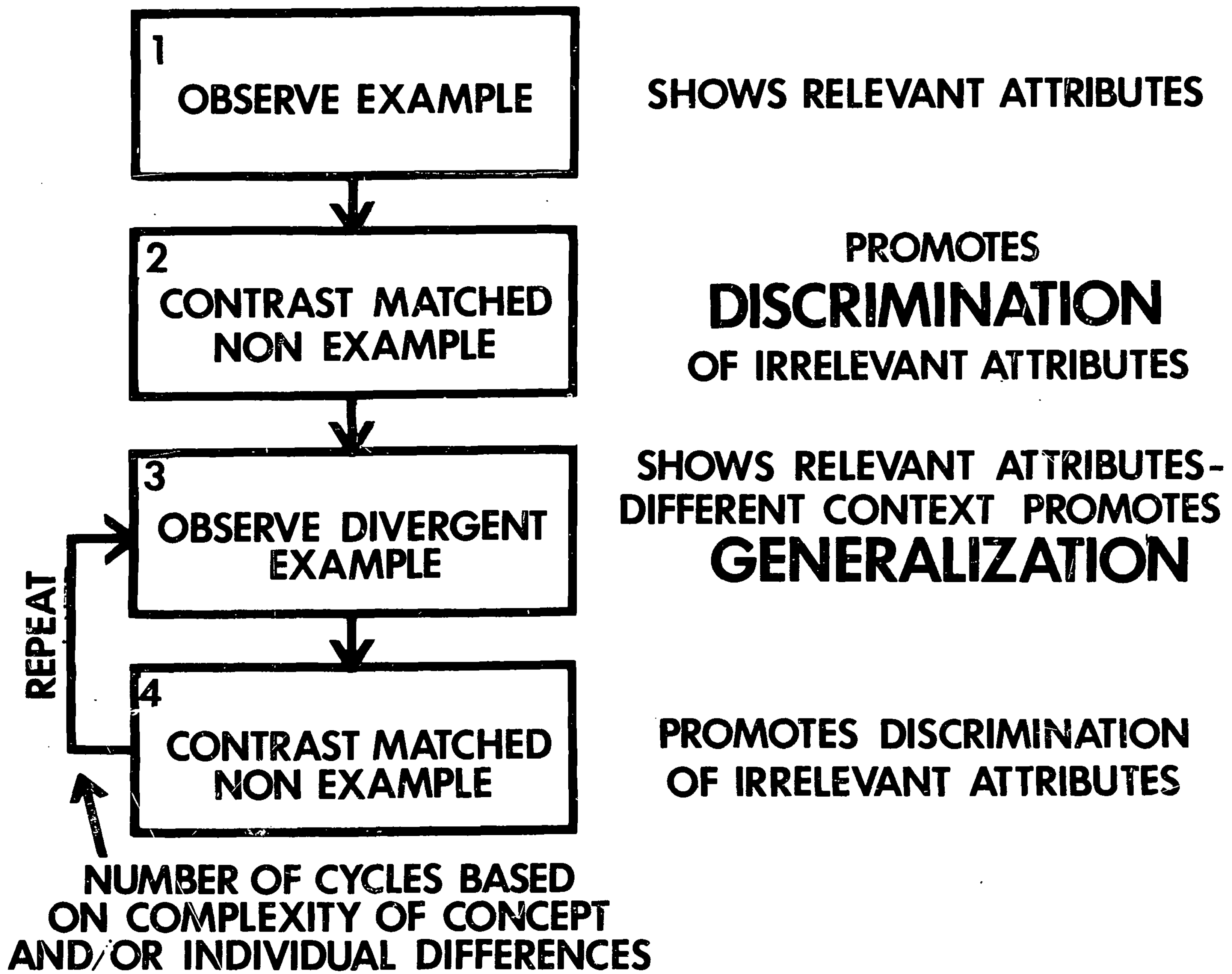


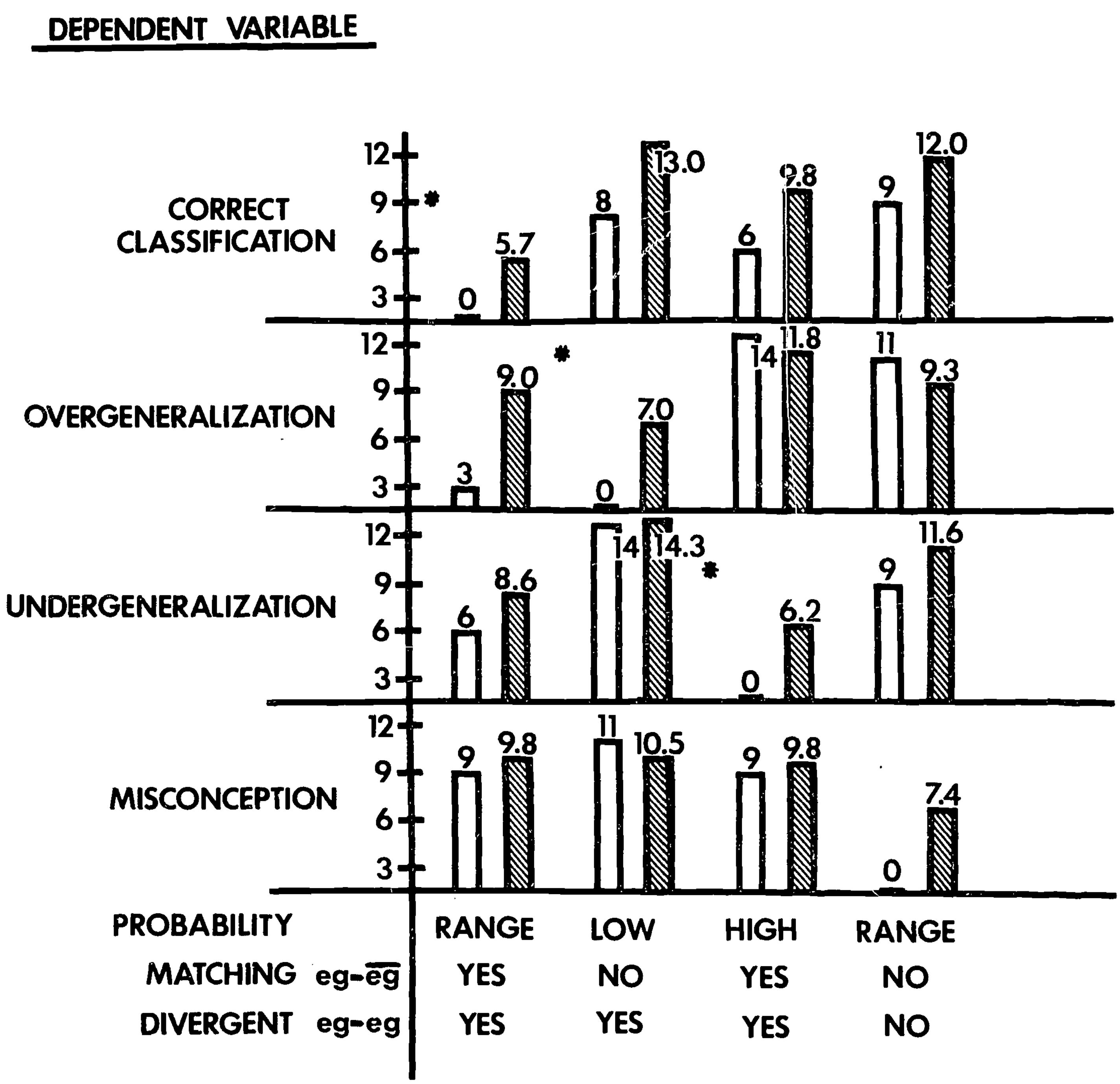
Fig. 4 HYPOTHESIZED OUTCOMES OF EXPERIMENTAL STUDY

## INDEPENDENT VARIABLES

PREDICTED OUTCOMES

| | PROBABILITY | MATCHED eg → eg | DIVERGENT eg → eg |
|---|---|---|---|
| CORRECT CLASSIFICATION | *RANGE* | *MATCHED* | *DIVERGENT* |
| OVER GENERALIZATION | *LOW or RANGE* | *UNMATCHED* | *DIVERGENT* |
| UNDER GENERALIZATION | *HIGH* | *MATCHED or UNMATCHED* | *DIVERGENT* |
| MISCONCEPTION | *RANGE* | *UNMATCHED* | *CONVERGENT* |

Fig. 5 RESULTS OF CONCEPT CLASSIFICATION STUDY



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FOOTNOTES

[1]This paper was prepared for presentation at the AECT 1971 convention, March 22-26, Philadelphia, Pennsylvania, in a session titled, "Toward a Definition of Instructional Development."

INSTRUCTIONAL RESEARCH & DEVELOPMENT
WORKING PAPERS

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